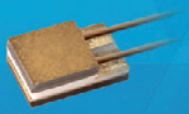
# MODEL 350
## ULTRA-LOW CRYOGENIC
# TEMPERATURE CONTROLLER

**Ideal for use with He-3 systems and other ultra-low temperature refrigeration platforms down to 100 mK**



OPTIMIZED
**CERNOX™**
PERFORMANCE

LakeShore

# Model 350 Ultra-Low Cryogenic Temperature Controller

- Ideal for use with He-3 systems and other ultra-low temperature refrigeration platforms down to 100 mK
- Optimized performance with Cernox™ RTDs
- Patented low-noise input circuitry enables super low excitation power for minimal self-heating and high resolution measurement
- 4 independent control loops and a broad range of I/O configurations can eliminate need for additional instrumentation
- 4 PID-controlled outputs: 75 W warm-up heater, 1 W sample heater, and 2 auxiliary 1 W ±10 V outputs
- Proven, intuitive interface
- Performance assurance even at the extremes, with verifiable product specifications
- Full 3 year standard warranty

## A Powerful Ultra-Low Temperature Physics Tool

The Model 350 is designed for the demands of pumped He-3 refrigerators and other ultra-low and low temperature platforms. It provides excellent measurement performance, superior control accuracy, and convenient operation in a wide range of advanced research applications. Whether the need is for high accuracy with minimal thermal impact, or precise temperature control in high magnetic fields, or dependable measurement in radiation environments, the new Model 350 controller matched with Lake Shore's industry-leading Cernox™ sensors provides a cryogenic solution that's demonstrably best-in-class.

The patented noise reduction input circuitry of the Model 350 is just one reason why this controller works so well for ultra-low temperature (ULT) applications, all the way down to 100 mK. When combined with precision Cernox sensors, this performance-optimized design allows as little as 10 nA of excitation current to be used, minimizing self-heating effects, and ensures best possible measurement accuracy throughout the entire temperature range.

This single instrument offers extraordinary capability and flexibility, often eliminating the need for additional instrumentation in a refrigeration control system. Its four input channels and four independent control outputs are configurable to support a broad range of I/O requirements, including the heaters and auxiliary devices typical of ULT refrigeration systems, as well as other cryogenic sensor types like ruthenium oxide and platinum RTDs. Standard computer interfaces enable remote communications, control and coordination with other systems.

In short, the Model 350 cryogenic temperature controller brings a new level of power, precision, and performance to critical low temperature physics research. It is ideal for use with He-3 systems, adiabatic demagnetization refrigerators (ADRs), certain dilution refrigerators, and many other applications demanding low thermal power and high measurement precision.

### Application Versatility

Designed to support a broad range of sensor types, the Model 350 is performance-optimized for use over the entire temperature range of Cernox™ sensors, making it the instrument of choice for ULT environments as well as other cryogenic systems where errors due to magneto-resistive or radiation effects need to be minimized.

#### 4 standard sensor input channels

The Model 350 comes with four standard sensor inputs supporting Cernox™, ruthenium oxide, platinum RTDs, and other NTC RTD sensors. Inputs can be configured to accept any of the supported input types. Each sensor input channel has its own current source, providing fast settling times. The four sensor inputs are optically isolated from other circuits to reduce noise and to provide repeatable sensor measurements. Current reversal eliminates thermal electromotive force (EMF) errors in resistance sensors. Nine excitation currents facilitate temperature measurement and control down to 100 mK, with the nominal temperature range (using Cernox™ sensors) spanning to 420 K. The instrument automatically selects the optimal current and gain levels for you once the

sensor type is selected, and automatically scales current to minimize self-heating effects at low temperatures. The patented input circuitry eliminates any errors associated with grounding inconsistencies, making it easier to achieve reliable measurements at ultra-low temperatures. With the ability to label each sensor input channel with a customized name, it's also easy to identify the measured values being displayed.

### 3 option cards for more inputs and a wider range of applications

Field installable input option cards can expand your sensor selection to include silicon diodes (like DT-670), capacitance sensors or thermocouples. Once installed, the option input can be selected and named from the front panel like any other input type. These option cards further expand the application versatility of the Model 350 temperature controller by allowing specialized sensors to be switched in and out to achieve specific measurement objectives. For example, addition of the thermocouple input option enables continuous measurement to 1000 K and above. Alternatively, the capacitance sensor option card enables a magnetics-impervious capacitance temperature sensor to be temporarily switched in for elimination of magneto-resistive effects while taking low temperature sample measurements under high or changing fields. Diode sensor support is provided by the 4-channel expansion card, which also enables use of additional Cernox™ sensors for supplemental monitoring.

### 4 PID controlled outputs

For convenient integration into a wide range of systems, the Model 350 offers four PID-controlled outputs. Variable DC current source outputs include a 75 W output for direct control of the typical main warm-up heater, and a 1 W output for fine control of the sample heater. Two additional 1 W variable DC voltage source outputs can be used to power auxiliary devices like a still heater in a dilution refrigerator, or to control a magnet power supply driving an ADR. The ability to dynamically select an input to associate with the controlled output provides additional flexibility in setting up the control scheme.

### Precision temperature control

The Model 350 calculates the precise control output based on your temperature setpoint and feedback from the control sensor. You can manually set the PID values for fine control, or the temperature control loop autotuning feature can automate the tuning process for you. The setpoint ramp feature provides smooth, continuous setpoint changes and predictable setpoint approaches without the worry of overshoot or excessive settling times. When combined with the zone setting feature, which enables automatic switching of sensor inputs and scales current excitation through ten different preloaded temperature zones, the Model 350 provides continuous measurement and control over the entire temperature range required.

## Simple and Increased Productivity

With remote control and automated features, the Model 350 will simplify your temperature control processes and increase your productivity in the laboratory.

### 3 interfaces for remote control

The Model 350 temperature controller includes Ethernet, USB, and IEEE-488 interfaces. In addition to gathering data, nearly every function of the instrument can be controlled through a computer interface. Ethernet provides the ability to access and monitor instrument activities via the internet from anywhere in the world, allowing distributed sharing of the controller and the controlled system. You can download the Lake Shore curve handler software to your computer to easily enter and manipulate sensor calibration curves for storage in the instrument's non-volatile flash memory.

### Simple automation

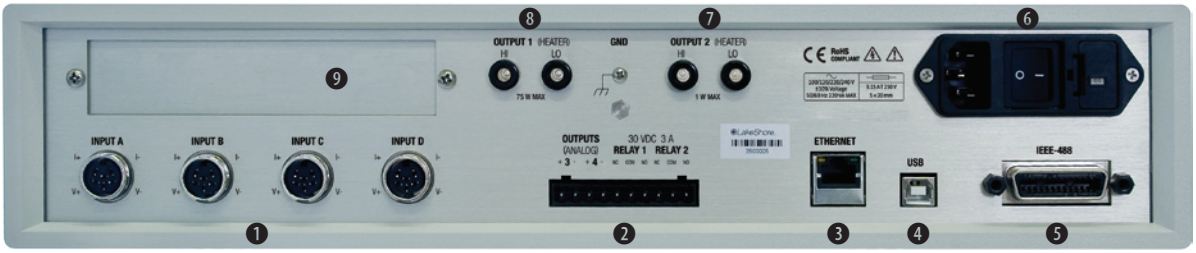
Each sensor input has a high and low alarm that offer latching and non-latching operation. The two relays can be used in conjunction with the alarms to alert you of a fault condition

and perform simple on/off control. Relays can be assigned to any alarm or operated manually. Choosing appropriate PID control settings for a closed loop system can be tedious, but the Model 350 provides the temperature control loop autotuning feature to simplify the process. It's an automated process that measures system characteristics and computes setting values for P, I, and D for you. Once PID tuning parameters are chosen for a given setpoint, the zone tuning feature automatically switches sensor inputs for new setpoints, enabling you to control temperatures from 100 mK to over 1000 K without interrupting your experiment.

## Performance You Can Count On

As with all Lake Shore products, the Model 350 product specifications are documented and verifiable in keeping with Lake Shore's tradition of performance assurance even at application extremes. The product is supported by a 3-year standard warranty, our confirmation of quality and commitment for the long term. Choosing the Model 350 for your ultra-low temperature application means you'll have the ultimate confidence in meeting your integration, measurement and control needs, now and into the future.

### Model 350 Rear Panel Connections



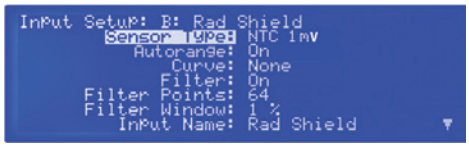

1. Sensor inputs
2. Terminal block (analog outputs & relays)
3. Ethernet interface
4. USB interface
5. IEEE-488 interface
6. Line input assembly
7. Output 2 heater
8. Output 1 heater
9. Option card slot

## Configurable Display

The Model 350 offers a bright, graphic liquid crystal display with an LED backlight that simultaneously displays up to eight readings. You can show all four loops, or if you need to monitor one input, you can display just that one in greater detail. Or you can custom configure each display location to suit your experiment. Data from any input can be assigned to any of the locations, and your choice of temperature or sensor units can be displayed. For added convenience, you can also custom label each sensor input, eliminating the guesswork in remembering or determining the location to which a sensor input is associated.

***Four Input/Output Display with Labels***
*Standard display option featuring all four inputs and associated outputs.*

***Two Input/Output Display with Labels***
*Reading locations can be user configured to meet application needs. Here, the input name is shown above each measurement reading along with the designated input letter.*




***Intuitive Menu Structure***
*Logical navigation allows you to spend more time on research and less time on setup.*

## Use Additional Input Types with Option Cards

The field installable input option cards add additional input types. The Model 3060 adds thermocouple capability. The Model 3061 adds capacitance sensor inputs. The Model 3062 adds 4 Cernox™/diode inputs. While the option cards can be easily removed, it is not necessary as the standard inputs remain functional when the options are not being used.

# Sensor Selection

### Sensor Temperature Range (sensors sold separately)

| | | Model | Useful range | Magnetic field use |
|---|---|---|---|---|
| **Negative Temperature Coefficient RTDs** | Cernox™ | CX-1010 | 0.1 K to 325 K[1] | T > 2 K & B ≤ 19 T |
| | Cernox™ | CX-1030-HT | 0.3 K to 420 K[1,] | T > 2 K & B ≤ 19 T |
| | Cernox™ | CX-1050-HT | 1.4 K to 420 K[1] | T > 2 K & B ≤ 19 T |
| | Cernox™ | CX-1070-HT | 4 K to 420 K[1] | T > 2 K & B ≤ 19 T |
| | Cernox™ | CX-1080-HT | 20 K to 420 K[1] | T > 2 K & B ≤ 19 T |
| | Germanium | GR-300-AA | 0.35 K to 100 K | Not recommended |
| | Germanium | GR-1400-AA | 1.8 K to 100 K | Not recommended |
| | Rox™ | RX-102B | 0.1 K to 40 K | T > 2 K & B ≤ 10 T |
| | Rox™ | RX-103 | 1.4 K to 40 K | T > 2 K & B ≤ 10 T |
| | Rox™ | RX-202 | 0.5 K to 40 K | T > 2 K & B ≤ 10 T |
| **Positive Temperature Coefficient RTDs** | 100 Ω platinum | PT-102/3 | 14 K to 873 K | T > 40 K & B ≤ 2.5 T |
| | 100 Ω platinum | PT-111 | 14 K to 673 K | T > 40 K & B ≤ 2.5 T |
| | Rhodium-iron | RF-800-4 | 1.4 K to 500 K | T > 77 K & B ≤ 8 T |
| **Diodes** ***3062 (coming soon)*** | Silicon diode | DT-670-SD | 1.4 K to 500 K | T ≥ 60 K & B ≤ 3 T |
| | Silicon diode | DT-670E-BR | 30 K to 500 K | T ≥ 60 K & B ≤ 3 T |
| | Silicon diode | DT-414 | 1.4 K to 375 K | T ≥ 60 K & B ≤ 3 T |
| | Silicon diode | DT-421 | 1.4 K to 325 K | T ≥ 60 K & B ≤ 3 T |
| | Silicon diode | DT-470-SD | 1.4 K to 500 K | T ≥ 60 K & B ≤ 3 T |
| | Silicon diode | DT-471-SD | 10 K to 500 K | T ≥ 60 K & B ≤ 3 T |
| | GaAlAs diode | TG-120-P | 1.4 K to 325 K | T > 4.2 K & B ≤ 5 T |
| | GaAlAs diode | TG-120-PL | 1.4 K to 325 K | T > 4.2 K & B ≤ 5 T |
| | GaAlAs diode | TG-120-SD | 1.4 K to 500 K | T > 4.2 K & B ≤ 5 T |
| **Capacitance** ***3061*** | | CS-501 | 1.4 K to 290 K | T > 4.2 K & B ≤ 18.7 T |
| **Thermocouples** ***3060-F*** | Type K | 9006-006 | 3.2 K to 1505 K | Not recommended |
| | Type E | 9006-004 | 3.2 K to 934 K | Not recommended |
| | Chromel-AuFe 0.07% | 9006-002 | 1.2 K to 610 K | Not recommended |

[1] *Non-HT version maximum temperature: 325 K*

**Cernox™** thin-film RTDs offer high sensitivity and low magnetic field-induced errors over the 0.1 K to 420 K temperature range. Cernox sensors require calibration.

**Platinum RTDs** offer high uniform sensitivity from 30 K to over 800 K. With excellent reproducibility, they are useful as thermometry standards. They follow a standard curve above 70 K and are interchangeable in many applications.

**Silicon diodes** are the best choice for general cryogenic use from 1.4 K to above room temperature. Silicon diodes are economical to use because they follow a standard curve and are interchangeable in many applications. They are not suitable for use in ionizing radiation or magnetic fields.

**Capacitance** sensors are ideally suited for use in strong magnetic fields because they exhibit virtually no magnetic field dependence. They can be used from 1.4 K to 290 K.

## Typical Sensor Performance

| | Example Lake Shore Sensor | Temperature (K) | Nominal Resistance/ Voltage | Typical Sensor Sensitivity[2] | Measurement Resolution: Temperature Equivalents | Electronic Accuracy: Temperature Equivalents | Temperature Accuracy including Electronic Accuracy, CalCurve™, and Calibrated Sensor | Electronic Control Stability[3]: Temperature Equivalents |
|---|---|---|---|---|---|---|---|---|
| Cernox™ (1 mV) | CX-1010-SD with 0.1L calibration | 0.1<br>0.3<br>0.5<br>4.2<br>300 | 21389 Ω<br>2322.4 Ω<br>1248.2 Ω<br>277.32 Ω<br>30.392 Ω | -558110 Ω/K<br>-10785 Ω/K<br>-2665.2 Ω/K<br>-32.209 Ω/K<br>-0.0654 Ω/K | 5.4 µK<br>28 µK<br>113 µK<br>931 µK<br>153 mK | ±69 µK<br>±272 µK<br>±938 µK<br>±6.5 mK<br>±1.7 K | ±4.1 mK<br>±4.3 mK<br>±4.9 mK<br>±11 mK<br>±1.8 K | ±10.8 µK<br>±55.6 µK<br>±225 µK<br>±1.9 mK<br>±306 mK |
| Cernox™ (10 mV) | CX-1050-SD-HT[4] with 1.4M calibration | 1.4<br>4.2<br>77<br>420 | 26566 Ω<br>3507.2 Ω<br>205.67 Ω<br>45.03 Ω | -48449 Ω/K<br>-1120.8 Ω/K<br>-2.4116 Ω/K<br>-0.0829 Ω/K | 6.2 µK<br>89 µK<br>1.2 mK<br>12 mK | ±261 µK<br>±2.1 mK<br>±38 mK<br>±338 mK | ±4.3 mK<br>±6.1 mK<br>±50 mK<br>±412 mK | ±12.4 µK<br>±178 µK<br>±2.5 mK<br>±24.1 mK |
| Germanium (1 mV) | GR-50-AA with 0.05A calibration | 0.1<br>0.3<br>0.5<br>1.4<br>4.2 | 2317 Ω<br>164 Ω<br>73.8 Ω<br>24.7 Ω<br>13.7 Ω | -71858 Ω/K<br>-964 Ω/K<br>-202.9 Ω/K<br>-13.15 Ω/K<br>-1.036 Ω/K | 4.2 µK<br>31.1 µK<br>49.3 µK<br>228 µK<br>2.9 mK | ±14 µK<br>±78 µK<br>±195 µK<br>±904 µK<br>±7.2 mK | ±4.0 mK<br>±4.1 mK<br>±4.2 mK<br>±4.9 mK<br>±11 mK | ±8.3 µK<br>±62.2 µK<br>±98.6 µK<br>±456 µK<br>±5.8 mK |
| Germanium (10 mV) | GR-300-AA with 0.3D calibration | 0.3<br>1.4<br>4.2<br>100 | 35180 Ω<br>448.6 Ω<br>94.46 Ω<br>2.72 Ω | -512200 Ω/K<br>-581.3 Ω/K<br>-26.56 Ω/K<br>-0.024 Ω/K | 2 µK<br>17 µK<br>38 µK<br>4.2 mK | ±47 µK<br>±481 µK<br>±1.8 mK<br>±151 mK | ±4.0 mK<br>±4.5 mK<br>±5.8 mK<br>±171 mK | ±3.9 µK<br>±34.4 µK<br>±75.3 µK<br>±8.3 mK |
| Germanium (10 mV) | GR-1400-AA with 1.4D calibration | 1.4<br>4.2<br>77<br>100 | 35890 Ω<br>1689 Ω<br>3.55 Ω<br>2.8 Ω | -94790 Ω/K<br>-861.9 Ω/K<br>-0.05 Ω/K<br>-0.021 Ω/K | 11 µK<br>35 µK<br>2 mK<br>4.8 mK | ±257 µK<br>±900 µK<br>±83 mK<br>±175 mK | ±4.3 mK<br>±4.9 mK<br>±94 mK<br>±195 mK | ±21.1 µK<br>±69.6 µK<br>±4 mK<br>±9.5 mK |
| Rox™ (1 mV) | RX-102B-CB with 0.02C calibration | 0.1<br>0.5<br>1.4<br>4.2<br>40 | 3549 Ω<br>2188 Ω<br>1779 Ω<br>1546 Ω<br>1199 Ω | -12578 Ω/K<br>-1056 Ω/K<br>-198 Ω/K<br>-40.0 Ω/K<br>-3.41 Ω/K | 79.5 µK<br>284 µK<br>1.5 mK<br>7.5 mK<br>88 mK | ±908 µK<br>±2.7 mK<br>±13.7 mK<br>±65.4 mK<br>±727 mK | ±4.9 mK<br>±6.7 mK<br>±18 mK<br>±69 mK<br>±803 mK | ±159 µK<br>±568 µK<br>±3.0 mK<br>±15.0 mK<br>±176 mK |
| Platinuim RTD 500 Ω Full Scale | PT-103 with 14J calibration | 30<br>77<br>300<br>500 | 3.66 Ω<br>20.38 Ω<br>110.35 Ω<br>185.668 Ω | 0.191 Ω/K<br>0.423 Ω/K<br>0.387 Ω/K<br>0.378 Ω/K | 0.5 mK<br>0.7 mK<br>7.8 mK<br>7.9 mK | ±22 mK<br>±34 mK<br>±140 mK<br>±223 mK | ±31 mK<br>±44 mK<br>±164 mK<br>±274 mK | ±1.0 mK<br>±1.4 mK<br>±15.5 mK<br>±15.9 mK |
| Silicon Diode | DT-670-CO-13 with 1.4H calibration | 1.4<br>77<br>300<br>500 | 1.664 V<br>1.028 V<br>0.5596 V<br>0.0907 V | -12.49 mV/K<br>-1.73 mV/K<br>-2.3 mV/K<br>-2.12 mV/K | 0.8 mK<br>5.8 mK<br>4.3 mK<br>4.7 mK | ±13 mK<br>±76 mK<br>±47 mK<br>±40 mK | ±20 mK<br>±113 mK<br>±82 mK<br>±94 mK | ±1.6 mK<br>±11.6 mK<br>±8.7 mK<br>±9.4 mK |
| Silicon Diode | DT-470-SD-13 with 1.4H calibration | 1.4<br>77<br>300<br>475 | 1.6981 V<br>1.0203 V<br>0.5189 V<br>0.0906 V | -13.1 mV/K<br>-1.92 mV/K<br>-2.4 mV/K<br>-2.22 mV/K | 0.8 mK<br>5.2 mK<br>4.2 mK<br>4.5 mK | ±13 mK<br>±68 mK<br>±44 mK<br>±38 mK | ±20 mK<br>±105 mK<br>±79 mK<br>±87 mK | ±1.5 mK<br>±10.4 mK<br>±8.3 mK<br>±9.0 mK |
| GaAlAs Diode | TG-120-SD with 1.4H calibration | 1.4<br>77<br>300<br>475 | 5.3909 V<br>1.4222 V<br>0.8978 V<br>0.3778 V | -97.5 mV/K<br>-1.24 mV/K<br>-2.85 mV/K<br>-3.15 mV/K | 0.21 mK<br>16 mK<br>7 mK<br>6.3 mK | ±6 mK<br>±179 mK<br>±60 mK<br>±37 mK | ±13 mK<br>±216 mK<br>±95 mK<br>±86 mK | ±410 µK<br>±32.3 mK<br>±14.0 mK<br>±12.7 mK |
| Capacitance | CS-501 | 4.2<br>77<br>200 | 6.0 nF<br>9.1 nF<br>19.2 nF | 27 pF/K<br>52 pF/K<br>174 pF/K | 7.4 mK<br>3.9 mK<br>12 mK | Not applicable | Calibration not available from Lake Shore | ±14.8 mK<br>±7.7 mK<br>±23 mK |
| Thermocouple | Type K | 75<br>300<br>600<br>1500 | -5862.9 µV<br>1075.3 µV<br>13325 µV<br>49813 µV | 15.6 µV/K<br>40.6 µV/K<br>41.7 µV/K<br>36.1 µV/K | 26 mK<br>9.9 mK<br>9.6 mK<br>11 mK | ±252 mK[5]<br>±38 mK[5]<br>±184 mK[5]<br>±718 mK[5] | Calibration not available from Lake Shore | ±51.3 mK<br>±19.7 mK<br>±19.2 mK<br>±22.2 mK |

[2] *Typical sensor sensitivities were taken from representative calibrations for the sensor listed*

[3] *Control stability of the electronics only, in an ideal thermal system*

[4] *Non-HT version maximum temperature: 325 K*

[5] *Accuracy specification does not include errors from room temperature compensation*

# Model 350 Specifications

## Input Specifications

| | Sensor Temperature Coefficient | Input Range | Excitation Current | Display Resolution | Measurement Resolution[6] | Electronic Accuracy (at 25 °C) | Measurement Temperature Coefficient | Electronic Control Stability[7] |
|---|---|---|---|---|---|---|---|---|
| NTC RTD/ PTC RTD 10 mV | Negative/ Positive | 0 Ω to 10 Ω | 1 mA[9] | 0.1 mΩ | 0.1 mΩ | ±0.002 Ω ±0.06% of rdg | (0.01 mΩ + 0.001% of rdg)/°C | ±0.2 mΩ |
| | | 0 Ω to 30 Ω | 300 µA[9] | 0.1 mΩ | 0.3 mΩ | ±0.002 Ω ±0.06% of rdg | (0.03 mΩ + 0.001% of rdg)/°C | ±0.6 mΩ |
| | | 0 Ω to 100 Ω | 100 µA[9] | 1 mΩ | 1 mΩ | ±0.01 Ω ±0.04% of rdg | (0.1 mΩ + 0.001% of rdg)/°C | ±2 mΩ |
| | | 0 Ω to 300 Ω | 30 µA[9] | 1 mΩ | 3 mΩ | ±0.01 Ω ±0.04% of rdg | (0.3 mΩ + 0.001% of rdg)/°C | ±6 mΩ |
| | | 0 Ω to 1 kΩ | 10 µA[9] | 10 mΩ | 10 mΩ | ±0.1 Ω ±0.04% of rdg | (1 mΩ + 0.001% of rdg)/°C | ±20 mΩ |
| | | 0 Ω to 3 kΩ | 3 µA[9] | 10 mΩ | 30 mΩ | ±0.1 Ω ±0.04% of rdg | (3 mΩ + 0.001% of rdg)/°C | ±60 mΩ |
| | | 0 Ω to 10 kΩ | 1 µA[9] | 100 mΩ | 100 mΩ | ±1.0 Ω ±0.04% of rdg | (10 mΩ + 0.001% of rdg)/°C | ±200 mΩ |
| | | 0 Ω to 30 kΩ | 300 nA[9] | 100 mΩ | 300 mΩ | ±2.0 Ω ±0.04% of rdg | (30 mΩ + 0.001% of rdg)/°C | ±600 mΩ |
| | | 0 Ω to 100 kΩ | 100 nA[9] | 1 Ω | 1 Ω | ±10.0 Ω ±0.04% of rdg | (100 mΩ + 0.001% of rdg)/°C | ±2 Ω |
| | | 0 Ω to 300 kΩ | 30 nA[9] | 1 Ω | 3 Ω | ±30 Ω ±0.04% of rdg | (300 mΩ + 0.001% of rdg)/°C | ±6 Ω |
| NTC RTD 1 mV | Negative | 0 Ω to 10 Ω | 100 µA[9] | 0.1 mΩ | 1 mΩ | ±0.01 Ω ±0.04% of rdg | (0.1 mΩ + 0.001% of rdg)/°C | ±2 mΩ |
| | | 0 Ω to 30 Ω | 30 µA[9] | 0.1 mΩ | 3 mΩ | ±0.01 Ω ±0.04% of rdg | (0.3 mΩ + 0.001% of rdg)/°C | ±6 mΩ |
| | | 0 Ω to 100 Ω | 10 µA[9] | 1 mΩ | 10 mΩ | ±0.1 Ω ±0.04% of rdg | (1 mΩ + 0.001% of rdg)/°C | ±20 mΩ |
| | | 0 Ω to 300 Ω | 3 µA[9] | 1 mΩ | 30 mΩ | ±0.1 Ω ±0.04% of rdg | (3 mΩ + 0.001% of rdg)/°C | ±60 mΩ |
| | | 0 Ω to 1 kΩ | 1 µA[9] | 10 mΩ | 100 mΩ | ±1.0 Ω ±0.04% of rdg | (10 mΩ + 0.001% of rdg)/°C | ±200 mΩ |
| | | 0 Ω to 3 kΩ | 300 nA[9] | 10 mΩ | 300 mΩ | ±2.0 Ω ±0.04% of rdg | (30 mΩ + 0.001% of rdg)/°C | ±600 mΩ |
| | | 0 Ω to 10 kΩ | 100 nA[9] | 100 mΩ | 1 Ω | ±10.0 Ω ±0.04% of rdg | (100 mΩ + 0.001% of rdg)/°C | ±2 Ω |
| | | 0 Ω to 30 kΩ | 30 nA[9] | 100 mΩ | 3 Ω | ±30 Ω ±0.04% of rdg | (300 mΩ + 0.001% of rdg)/°C | ±6 Ω |
| | | 0 Ω to 100 kΩ | 10 nA[9] | 1 Ω | 10 Ω | ±100 Ω ±0.04% of rdg | (1 Ω + 0.001% of rdg)/°C | ±20 Ω |
| Diode[11] | Negative | 0 V to 2.5 V | 10 µA ±0.05%[8] | 100 µV | 10 µV | ±80 µV ±0.005% of rdg | (10 µV + 0.0005% of rdg)/°C | ±20 µV |
| | Negative | 0 V to 10 V | 10 µA ±0.05%[8] | 100 µV | 20 µV | ±80 µV ±0.01% of rdg | (20 µV + 0.0005% of rdg)/°C | ±40 µV |
| Thermocouple[11] | Positive | ±50 mV | NA | 0.1 µV | 0.4 µV | ±1 µV ±0.05% of rdg[10] | (0.1 µV + 0.001% of rdg)/°C | ±0.8 µV |
| Capacitance[11] | Positive or Negative | 0.1 to 15 nF | 3.496 kHz 1 mA square wave | 0.1 pF | 0.2 pF | ±30 pF ±0.1% of rdg | 2.5 pF/°C | 0.4 pF |
| | | 1 to 150 nF | 3.496 kHz 10 mA square wave | 1 pF | 2 pF | ±300 pF ±0.1% of rdg | 5 pF/°C | 4 pF |

[6] *Measurement resolution of the electronics only (with thermal noise of the resistor removed)*
[7] *Control stability of the electronics only, in ideal thermal system*
[8] *Current source error has negligible effect on measurement accuracy*
[9] *Current source error is removed during calibration*
[10] *Accuracy specification does not include errors from room temperature compensation*
[11] *Option card required*

## Thermometry

**Number of inputs** 4

**Input configuration** Inputs can be configured from the front panel to accept any of the supported input types. Thermocouple, capacitance and diode inputs require an optional input card that can be installed in the field. Once installed, the additional inputs can be selected from the front panel like any other input type.

**Isolation** Sensor inputs optically isolated from other circuits but not each other

**A/D resolution** 24-bit

**Input accuracy** Sensor dependent, refer to Input Specifications table

**Measurement resolution** Sensor dependent, refer to Input Specifications table

**Maximum update rate** 10 rdg/s on each input

**Autorange** Automatically selects appropriate NTC RTD or PTC RTD range

**User curves** Room for 39 200-point CalCurves™ or user curves

**SoftCal™** Improves accuracy of DT-470 diode to ±0.25 K from 30 K to 375 K; improves accuracy of platinum RTDs to ±0.25 K from 70 K to 325 K; stored as user curves

**Math** Maximum and minimum

**Filter** Averages 2 to 64 input readings

**Excitation frequency** 10 Hz squarewave

## Sensor Input Configuration

| | RTD | Diode (option) | Thermocouple (option) | Capacitance (option) |
|---|---|---|---|---|
| **Measurement type** | 4-lead differential | 4-lead differential | 2-lead differential, room temperature compensated | 4-lead differential, variable duty cycle |
| **Excitation** | Constant current with current reversal | 10 µA constant current | N/A | Constant current, 4.88 kHz |
| **Supported sensors** | 100 Ω Platinum, 1000 Ω Platinum, Germanium, Carbon-Glass, Cernox™, and Rox™ | Silicon, GaAlAs | Most thermocouple types | CS-501GR |
| **Standard curves** | PT-100, PT-1000, RX-102A, RX-202A | DT-470, DT-670, DT-500-D, DT-500-E1 | Type E, Type K, Type T, AuFe 0.07% vs. Cr, AuFe 0.03% vs Cr | N/A |
| **Input connector** | 6-pin DIN | 6-pin DIN | Screw terminals in a ceramic isothermal block | 6-pin DIN |

## Control

**Control outputs** 4

## Heater outputs (Outputs 1 & 2)

**Control type** Closed loop digital PID with manual heater output or open loop
**Update rate** 10/s
**Tuning** Autotune (one loop at a time), PID, PID zones
**Control stability** Sensor dependent, see Input Specifications table
**PID control settings**
- **Proportional (gain)** 0 to 9999 with 0.1 setting resolution
- **Integral (reset)** 1 to 1000 (1000/s) with 0.1 setting resolution
- **Derivative (rate)** 1 to 200% with 1% resolution
- **Manual output** 0 to 100% with 0.01% setting resolution

**Zone control** 10 temperature zones with P, I, D, manual heater out, heater range, control channel, ramp rate
**Setpoint ramping** 0.001 K/min to 100 K/min

## Output 1

| | 25 Ω setting | 50 Ω setting |
|---|---|---|
| **Type** | Variable DC current source | |
| **D/A resolution** | 16-bit | |
| **Max power** | 75 W | 50 W |
| **Max current** | 1.732 A | 1 A |
| **Voltage compliance (min)** | 50 V | 50 V |
| **Heater load for max power** | 25 Ω | 50 Ω |
| **Heater load range** | 10 Ω to 100 Ω | |
| **Ranges** | 5 (decade steps in power) | |
| **Heater noise** | 1.2 µA RMS (dominated by line frequency and its harmonics) | |
| **Grounding** | Output referenced to chassis ground | |
| **Heater connector** | Dual banana | |
| **Safety limits** | Curve temperature, power up heater off, short circuit protection | |

## Output 2

| | |
|---|---|
| **Type** | Variable DC current source |
| **D/A resolution** | 16-bit |
| **Max power** | 1 W |
| **Max current** | 100 mA |
| **Voltage compliance (min)** | 10 V |
| **Heater load for max power** | 100 Ω |
| **Heater load range** | 25 Ω to 2 kΩ |
| **Ranges** | (100 Ω load) 1 W, 100 mW, 10 mW, 1 mW, 100 µW |
| **Heater noise** | <0.005% of range |
| **Grounding** | Output referenced to measurement common |
| **Heater connector** | Dual banana |
| **Safety limits** | Curve temperature, power up heater off, short circuit protection |

## Analog outputs (Outputs 3 & 4)

**Control type** Closed loop PID, PID zones, warm up heater mode, still heater, ADR control, manual output, or monitor output
**Warm up heater mode settings**
- **Warm up percentage** 0 to 100% with 1% resolution
- **Warm up mode** Continuous control or auto-off

**Monitor output settings**
- **Scale** User selected
- **Data source** Temperature or sensor units
- **Settings** Input, source, top of scale, bottom of scale, or manual

**Type** Variable DC voltage source
**Update rate** 10/s
**Range** ±10 V
**Resolution** 16-bit, 0.3 mV
**Accuracy** ±2.5 mV
**Noise** 0.3 mV RMS
**Maximum current** 100 mA
**Maximum power** 1 W (into 100 Ω)
**Minimum load resistance** 100 Ω (short-circuit protected)
**Connector** Detachable terminal block

## Front Panel

**Display** 8-line by 40-character (240 × 64 pixel) graphic LCD display module with LED backlight
**Number of reading displays** 1 to 8
**Display units** K, °C, V, mV, Ω
**Reading source** Temperature, sensor units, max, and min
**Display update rate** 2 rdg/s
**Temperature display resolution** 0.00001° from 0° to 9.99999°, 0.0001° from 10 to 99.9999°, 0.001° from 100° to 999.999°, 0.01° above 1000°
**Sensor units display resolution** Sensor dependent, to 6 digits
**Other displays** Input name, setpoint, heater range, heater output, and PID
**Setpoint setting resolution** Same as display resolution (actual resolution is sensor dependent)
**Heater output display** Numeric display in percent of full scale for power or current
**Heater output resolution** 0.01%
**Display annunciators** Control input, alarm, tuning
**LED annunciators** Remote, Ethernet status, alarm, control outputs
**Keypad** 27-key silicone elastomer keypad
**Front panel features** Front panel curve entry, display contrast control, and keypad lock-out

## Interface

**IEEE-488.2**
- **Capabilities** SH1, AH1, T5, L4, SR1, RL1, PP0, DC1, DT0, C0, E1
- **Reading rate** To 10 rdg/s on each input
- **Software support** LabVIEW™ driver (contact Lake Shore for availability)

**USB**
- **Function** Emulates a standard RS-232 serial port
- **Baud rate** 57,600
- **Connector** B-type USB connector
- **Reading rate** To 10 rdg/s on each input
- **Software support** LabVIEW™ driver (contact Lake Shore for availability)

**Ethernet**
- **Function** TCP/IP, web interface, curve handler, configuration backup
- **Connector** RJ-45
- **Reading rate** To 10 rdg/s on each input
- **Software support** LabVIEW™ driver (contact Lake Shore for availability)

**Alarms**
- **Number** 4, high and low for each input
- **Data source** Temperature or sensor units
- **Settings** Source, high setpoint, low setpoint, deadband, latching or non-latching, audible on/off, and visible on/off
- **Actuators** Display annunciator, beeper, and relays

**Relays**
- **Number** 2
- **Contacts** Normally open (NO), normally closed (NC), and common (C)
- **Contact rating** 30 VDC at 3 A
- **Operation** Activate relays on high, low, or both alarms for any input, or manual mode
- **Connector** Detachable terminal block

## General

**Ambient temperature** 15 °C to 35 °C at rated accuracy; 5 °C to 40 °C at reduced accuracy
**Power requirement** 100, 120, 220, 240 VAC, ±10%, 50 or 60 Hz, 220 VA
**Size** 435 mm W × 89 mm H × 368 mm D (17 in × 3.5 in × 14.5 in), full rack
**Weight** 7.6 kg (16.8 lb)
**Approval** CE mark (contact Lake Shore for availability)

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*Established in 1968, Lake Shore Cryotronics, Inc. is an international leader in developing innovative measurement and control solutions. Founded by Dr. John M. Swartz, a former professor of electrical engineering at the Ohio State University, and his brother David, Lake Shore produces equipment for the measurement of cryogenic temperatures, magnetic fields, and the characterization of the physical properties of materials in temperature and magnetic environments.*

## Ordering Information

| Part number | Description |
|---|---|
| **350** | 4 input and 4 control output temperature controller |
| **3060-F** | 2-thermocouple input option |
| **3061** | Capacitance input option |
| **3062** | Cernox™ expansion/diode input option *(coming soon)* |

**Specify line power option***

| | |
|---|---|
| **VAC-100** | Instrument configured for 100 VAC with U.S. power cord |
| **VAC-120** | Instrument configured for 120 VAC with U.S. power cord |
| **VAC-120-ALL** | Instrument configured for 120 VAC with U.S. power cord and universal Euro line cord and fuses for 220/240 VAC setting |
| **VAC-220** | Instrument configured for 220 VAC with universal Euro line cord |
| **VAC-240** | Instrument configured for 240 VAC with universal Euro line cord |

**Other country line cords available, consult Lake Shore*

**Accessories included**

| | |
|---|---|
| **106-009** | Heater output connector (dual banana jack) |
| **G-106-233** | Sensor input mating connector (6-pin DIN plug); 4 included |
| **G-106-750** | Terminal block, 10-pin |
| **——** | Calibration certificate |
| **MAN-350** | Model 350 user manual |

**Accessories available**

| | |
|---|---|
| **6201** | 1 m (3.3 ft long) IEEE-488 (GPIB) computer interface cable assembly |
| **8001-350** | CalCurve™, factory installed—the breakpoint table from a calibrated sensor stored in the instrument (extra charge for additional sensor curves) |
| **CAL-350-CERT** | Instrument recalibration with certificate |
| **CAL-350-DATA** | Instrument recalibration with certificate and data |

*All specifications are subject to change without notice* 060412